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Guided Missile Personnel Research: Report No. 3

A PROFICIENCY TEST BATTERY FOR GUIDED MISSILE TECHNICIANS

Prepared under the Sponsorship of the
BUREAU OF NAVAL PERSONNEL

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B U R E A U   O F   N A V A L   P E R S O N N E L

* RESEARCH REPORT *

Guided Missile Personnel Research: Report No. 3

A PROFICIENCY TEST BATTERY FOR GUIDED MISSILE TECHNICIANS

by

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August 1953

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TRAINING RESEARCH BRANCH AND
BILLET AND QUALIFICATIONS RESEARCH BRANCH,
PERSONNEL ANALYSIS DIVISION

50

PREFACE

The human factors involved in the operation and maintenance of guided missiles are variables which must be considered in determining the reliability of the weapon. The over-all reliability is a resultant of the reliabilities of the individual components of the weapon system. The reliabilities of the components of the system are, in turn, a function of the following variables:

1. The basic principles of the operation of the weapon.
2. The design of the weapon.
3. Engineering testing and evaluation.
4. Fabrication and production.
5. Production inspection and quality control.
6. Transportation (handling), assembly and stowage.
7. Preflight check-out.
8. Trouble-shooting.
9. Servicing and repair.
10. The tactical use of the weapon.

Variables 1 through 5 are usually considered to be the responsibility of the missile designer and manufacturer and Navy engineering, human engineering, and inspection agencies. It is, however, variables 6 through 9 in the above list which largely reflects the adequacy of personnel selection, training, and job structure. The proficiency of Naval personnel in performing the tasks associated with variables 6 through 9 significantly contribute to the reliability of a particular guided missile.

Toward this objective and in order to base personnel plans and policy on sound objective data, the Personnel Analysis Division of the Bureau of Naval Personnel has planned a program of systematic guided missile personnel research. The procedures developed and the data obtained in this program can contribute to the following:

1. The specification of the knowledges and skills required by personnel to perform the job behaviors associated with the tasks required by the new weapon.
2. A comparison of the knowledges and skills required by the new weapon with the knowledges and skills available in existing manpower.

3. Recommendations for an efficient job structure for personnel concerned with the new weapon.
4. The development of on-the-job criteria of job effectiveness.
5. Recommendations for the selection and training of personnel to operate and maintain the new weapon.
6. The development and construction of tests of job proficiency.
7. Recommendations for the most efficient organization and use of operations and maintenance manpower.

In the guided missile personnel research program during the period from July 1952 to July 1953, the project undertaken by the American Institute for Research has been concerned primarily with the following objectives:

1. The compilation of task information for Terrier missile activities.
2. The development of testing procedures and methodology for measuring the proficiency of personnel who perform duties associated with the operation and maintenance of Terrier.

The work accomplished toward these objectives are reported in the following two reports:

A. Guided Missile Personnel Research: Report No. 2
   Part One: Collecting and Compiling Task Information for Newly Developed Guided Missiles.
   Part Two: A Compilation of Task Information for Terrier Missile Activities.

B. Guided Missile Personnel Research: Report No. 3
   A Proficiency Test Battery for Guided Missile Technicians.

Report No. 3 is presented here.

ABSTRACT

This report presents and discusses the development of a series of proficiency tests for Terrier guided missile technicians. These tests can be used to assess men at the end of training or may be used as training aids to facilitate learning.

Three kinds of multiple choice tests were developed:

1. A Testing and Adjustment Test which measures proficiency in the performance of specific testing, adjustment and servicing procedures; in the interpretation of test and adjustment results; and in the making of decisions concerning the proper equipment or procedures to employ.
2. A Trouble-Shooting Test which measures proficiency in the interpretation of symptoms of malfunctioning and in isolating trouble to particular components of a system.
3. A Knowledge of Operation Test which measure proficiency in the application and adaptive use of the principles of equipment functioning.

A new technique, called the Trouble-Shooting Formboard, is presented which has wide applicability as both a proficiency measurement and a training aid device. The Trouble-Shooting Formboard realistically permits a trainee to observe a symptom of equipment malfunctioning, to perform a series of checks and obtain information from these checks, and on the basis of this information to investigate units until the defective unit is located. This is accomplished without the use of the actual equipment.

The multiple-choice tests and the formboard items are presented in appendices included in this report.

ACKNOWLEDGMENTS

Very special appreciation is due to the officers and men of the Terrier guided missile training and service units. The enthusiastic and intelligent cooperation of these individuals contributed significantly to the research efforts upon which this report is based.

Appreciation is due to the Personnel Analysis Division of the Bureau of Naval Personnel for the encouragement of objective research and evaluation procedures in the guided missile personnel research program. Mr. Edward J. Fallon, who served as scientific liaison officer, deserves mention for his efforts in this capacity.

The Personnel and Training Branch, Psychological Sciences Division of the Office of Naval Research should also be mentioned for the encouragement of objective research procedures. Mr. Louis J. Sparvero, Resident Representative of the Office of Naval Research in Pittsburgh should be thanked for his cooperation in liaison matters.

Acknowledgment should be made to Dr. John C. Flanagan, Director of Research and Dr. Elmer D. West, Deputy Director for Administration and Research, both of the American Institute for Research, for their suggestions and assistance in the course of the research project.

Special mention needs to be made of the consultant engineering staff of the project who contributed wherever technical engineering knowledge was required and who served as test item writers. The members of this staff were

Dr. J. Frank Pierce
Prof. Wesley M. Rohrer, Jr.
Prof. George E. Jones, Jr.
Dr. John H. Neiler

all of the University of Pittsburgh.

CONTENTS

A PROFICIENCY TEST BATTERY FOR GUIDED MISSILE TECHNICIANS

INTRODUCTION

The ultimate objective of a personnel program associated with a particular guided missile is to maximize the reliability of this weapon. Reliability is enhanced when all variables influencing the weapon are controlled within the necessary tolerances; a list of these variables is given in the preface to this report. The output of a training program, i.e., the quality of performance of the personnel trained in the program, directly affects weapon reliability. An effective way of controlling this source of variation is through the use of job-oriented proficiency examinations. Proficiency tests provide a standard to which the finished product, the trained technician, must conform before being sent to perform his function in contributing to weapon reliability. It is important that control of the quality of the technician should take place on two levels: (1) a content level which is a function of the subject matter content of the proficiency examinations, and, (2) a behavioral level which is a function of the kind of behaviors and performances that are required with respect to this content.

This report discusses the development of an experimental battery of proficiency tests for Terrier guided missile technicians. Work on this battery has concentrated on the development of tests that do not require the use of actual equipment. (At the present stage of the missile program, equipment performance tests requiring the use of the critical gear which must be diverted from weapon evaluation activities is not feasible.) The underlying aim of the experimental battery is to develop tests which do not require actual equipment but which are highly correlated with performance tasks, and to identify those tasks which are and those tasks which are not practically amenable to testing without actual equipment. If acceptable validities are obtained for these kinds of tests, it is advisable to keep equipment tests in a testing program to a minimum.

The experimental battery developed consists of a set of proficiency tests which can be used to assess men at the end of training. However, in many instances the tests may be used as training examinations to facilitate learning. The initial stage of becoming proficient, which involves knowledge of nomenclature and the identification of parts, is not measured *per se* in the experimental test battery; that is, there is no separate nomenclature and identification test. These behaviors are usually part of such job behaviors as checking and trouble-shooting, and are tested as such in the test battery.

The test battery concentrates on the technical jobs which the guided missile technician performs on the missile and its associated test and servicing equipment. Guided missile jobs which are included in the tasks performed by Gunner's Mates and Fire Control Technicians are not covered in the battery. A description of the tasks performed by guided missile technicians in comparison with the guided missile tasks performed by these other ratings is presented in Guided Missile Personnel Research: Report No. 2, Part Two. A Compilation of Task Information for Terrier Missile Activities.

The present report describes a multiple-choice test battery consisting of three kinds of tests, namely, testing and alignment, trouble-shooting, and knowledge of operation. A new technique called the trouble-shooting formboard is also presented. This technique can be employed both as a proficiency test and a training device for trouble-shooting tasks.

CHAPTER I

THE MULTIPLE-CHOICE TEST BATTERY

The development of the multiple-choice portion of the Terrier Proficiency Test battery is described in three sections:

1. The Behavior Measured
2. The Content Covered
3. Test Construction

The Behavior Measured

Analysis of the job of the Terrier missile technician indicates three major kinds of job behavior that should be included in a proficiency test battery:

a. Testing and Adjustment

b. Trouble-Shooting

c. Knowledge of Operation

Testing and Adjustment

Testing and adjustment procedures involve job behavior such as the performance of specific manipulatory procedures, the interpretation of test or adjustment results, and the making of decisions concerning the proper equipment or procedures to employ. (Testing and adjustment for the Terrier missile is described in Guided Missile Personnel Research Report No. 2. Part II; A Compilation of Task Information for Terrier Missile Activities)

The task of the test technician is to construct test item situations which evoke examinee behavior that is closely related to the behavior required for job performances. Examples of the kinds of test item situations that are employed in the testing and adjustment test are given below. For each item type, the "situation given" and the "examinee behavior" on a multiple-choice item is described. The actual test items are presented in Appendix A.

Situation Given:	A check or adjustment to be made.
Examinee Behavior:	Select the test equipment(s) used to make this check or adjustment.
Situation Given:	A component has been installed.
Examinee Behavior:	Select the first step in adjusting it.
Situation Given:	A circuit condition and a desired change in the condition.
Examinee Behavior:	Select the adjustment that can accomplish this.
Situation Given:	An out-of-tolerance test result.
Examinee Behavior:	Select the correct adjustment procedure.
Situation Given:	A function to be checked and the appropriate test procedure.
Examinee Behavior:	Select the correct test panel knob and switch positions.
Situation Given:	An adjustment to be made.
Examinee Behavior:	Select the correct test equipment dial settings.
Situation Given:	A testing or servicing procedure to be performed.
Examinee Behavior:	Select the correct sequence of operations.
Situation Given:	A test signal or other test indication.
Examinee Behavior:	Identify how the equipment is functioning.
Situation Given:	In the course of a sequence of operations a step is omitted or performed incorrectly.
Examinee Behavior:	Select the consequences of this malpractice.
Situation Given:	Alternate results of a test.
Examinee Behavior:	Select the result that does not indicate a test equipment fault.
Situation Given:	A test set-up is presented which shows component interconnections.
Examinee Behavior:	Identify the connections between components.
Situation Given:	A dial or knob adjustment is performed.
Examinee Behavior:	Identify what this accomplishes.
Situation Given:	The name of an equipment.
Examinee Behavior:	Identify what components of this equipment should be checked most frequently.
Situation Given:	The name of a test equipment.
Examinee Behavior:	Identify what it is used to measure or check.

Trouble-Shooting

Trouble-shooting behavior involves the interpretation of indications or symptoms of malfunctioning; on the basis of these symptoms, a technician isolates a trouble to a particular component of a system. (Trouble-shooting behavior for the Terrier missile is described in Guided Missile Personnel Research: Report No. 2, Part II. A Compilation of Task Information for Terrier Missile Activities).

Multiple-choice test items to measure trouble-shooting proficiency present the examinee with a description or indication of malfunctioning and require him to select the faulty component. For piloted aircraft or equipment that is used over again, many malfunctions are reported by the using operator; for guided missiles, malfunctions are observed as a result of pre-flight tests in the course of making adjustments or as a result of assembly and launching difficulties. Maintenance data reports, offer excellent source material for trouble-shooting test items. These reports (see Report No.2) are obtained from the field and describe a casualty, its symptom, how it was located and how it was corrected. The multiple-choice trouble-shooting test items in the Terrier proficiency test battery are presented in Appendix A.

Knowledge of Operation

In the military situation there exist two conflicting goals of training. One goal is to train a man quickly to operate and maintain a specific piece of gear; the other goal is to train a man so that he can readily adapt to new equipment, assimilate modifications in old equipment, and handle a piece of equipment in emergency or non-standard situations. The first goal requires a specific kind of training; the second goal a more general training. A compromise between these two goals is necessary, and a proficiency test battery should be oriented toward each of these goals.

The Testing and Adjustment Test and the Trouble-Shooting Test are oriented toward specific on-the-job tasks. The Knowledge of Operation Test is oriented toward the second goal and tests the application of general principles of equipment functioning. "Application" is the key term here. The examinee is not asked primarily to recall principles he remembers, but to use these principles to solve a problem. The examinee is given problem situations concerned with particular gear, in this case Terrier and Terrier test equipment, in which he must use principles underlying the operation and functioning of this gear to solve practical problems.

The kind of knowledge tested with the Knowledge of Operation test can be called transferrable knowledge and is hypothesized to be characteristic of individuals who are capable of adaptive job behavior. Behavior of this kind can be evoked in stimulus settings where an individual cannot respond entirely on the basis of rote learning or straight memory. In the construction of items for this test, the attempt is made to reduce memory to a minimum by giving the examinee all the information he would have on the job in terms of circuit diagrams, pre-test information, etc.; he is then presented with a test situation which requires the application of job-oriented knowledge. Test items of low difficulty level on this kind of test appear to be close to straight memory items and probably can be answered either on this basis or through a knowledge of equipment operation; items of higher difficulty appear to require the application of knowledge.

Examples of the kinds of test item situations that are employed in the Knowledge of Operations test are given below. For each item type, the "situation given" and the "examinee behavior" on a multiple-choice item is described. The actual test items are presented in Appendix A.

Given Situation:	Input to a circuit and a defective component.
Examinee Behavior:	Identify the output signal.
Given Situation:	An input waveform to a circuit or component.
Examinee Behavior:	Identify the correct output waveform.
Given Situation:	A change in circuit input.
Examinee Behavior:	Identify the change in output.
Given Situation:	A change in one aspect of a circuit that results in a certain effect.
Examinee Behavior:	Select another change that would produce the same effect.
Given Situation:	A change in circuit input from correct to incorrect.
Examinee Behavior:	Select the part of the system that would not function properly.
Given Situation:	A component becomes defective and operates incorrectly.
Examinee Behavior:	Identify how the equipment now functions.
Given Situation:	A piece of test gear and a circuit or component.
Examinee Behavior:	Identify the indication on the test gear that indicates that the component is functioning properly.

Given Situation:	An indication in a test instrument.
Examinee Behavior:	Select the equipment condition that determines this indication.
Given Situation:	A description of equipment performance and a change in the circuit.
Examinee Behavior:	Identify how the equipment performance changes.
Given Situation:	A description of an equipment performance.
Examinee Behavior:	Identify what occurs in a particular circuit.
Given Situation:	A description of an equipment performance.
Examinee Behavior:	Identify what occurs in a particular circuit just prior to this performance.
Given Situation:	The name of a type of circuit.
Examinee Behavior:	Select the diagram that best represents this circuit.
Given Situation:	A function of a circuit and diagrams of alternate circuits.
Examinee Behavior:	Select the circuit that best or correctly performs this function.
Given Situation:	A block diagram.
Examinee Behavior:	Identify the unlabeled blocks.
Given Situation:	A block diagram.
Examinee Behavior:	Identify connections between blocks.
Given Situation:	A description of equipment functioning.
Examinee Behavior:	Select the explanation of this functioning.
Given Situation:	A defective component and the resultant effect upon equipment performance.
Examinee Behavior:	Select the best explanation or reason for this result.
Given Situation:	A sequence of operations that is performed incorrectly.
Examinee Behavior:	Identify the malfunction that will occur.
Given Situation:	The name of a particular control.
Examinee Behavior:	Identify how it performs its function.
Given Situation:	A series of components which perform particular functions.
Examinee Behavior:	Select the best description of how they operate.

General Comment

In the construction of the items in the Terrier Proficiency Test Battery, detailed care has been taken to keep verbal facility required by the examinee to a minimum. This has been done by being succinct, using job language, and by using diagrams wherever applicable. Fewer words are probably required on the job; however, whether or not this verbal aspect significantly attentuates the validity of tests of this sort is a matter to be investigated.

The Content Covered

Three criteria were employed as a basis for recommendations concerning the sampling emphasis of the test battery content: (1) The importance of components in the over-all operation of the missile system as judged by the project engineers; (2) The complexity of the job procedures concerned with a component or test equipment as judged by engineers and job analysts; (3) The amount and extent of trouble reported or reported likely for certain components and equipment by engineers and operating personnel.

Testing and Adjustment: Since testing and adjustment is primarily concerned with the use and interpretation of test equipment, most emphasis in this test is placed on test and servicing equipment as compared with missile components. Approximately two-thirds of the items are primarily concerned with test and servicing equipment and one-third with missile components.

Trouble-Shooting: Trouble-shooting is concerned with both missile components and test equipment. On-the-job performance is primarily oriented around the location of troubles in the missile. Two-thirds of the items in this test are concerned with missile components and one-third with test and servicing equipment.

Knowledge of Operations: This test is primarily oriented around the operation of missile components. Four-fifths of the items are primarily concerned with missile components and one-fifth with test and servicing equipment.

The separation made above between items concerned with missile components and items concerned with test and servicing equipment is somewhat arbitrary and artificial. Many items are not exclusively in one category or the other, but categorization facilitates the control of the sampling of test content.

A detailed break-down of the three tests listing the number of items for each missile component and separate pieces of test and servicing equipment is as follows:

	Testing and Adjustment	Trouble-Shooting	Knowledge of Operations
Missile Components			
Receiver	3	9	16
Guidance System	5	10	23
Electrical System (Power Supply and Switching)	5	10	9
Air and Hydraulic System	2	5	5
General Missile System	3	4	4
Test and Servicing Equipment			
Hydraulic Charging Unit	4	3	3
Monitoring Panel	17	9	7
Flight Ready Indicator	2	4	3
Guidance Analyser	9	3	3
	50	57	73

For the following reasons a number of pieces of proposed test equipment to be used with Terrier were not included in the experimental test battery: (a) Adequate technical materials were not available to the American Institute for Research. (b) The equipment was newly introduced in the field or infrequently used by operating personnel. (c) Technical materials were received after the test was prepared for administration at a particular time. These pieces of equipment are the Beam Simulator, the Beam Simulator Test Unit, the Receiver Test Unit, the Monitoring Panel Test Unit and the BuOrd Functional Test Equipment (Hycon).

Construction of the Tests

The construction of proficiency tests for personnel working with complex equipment requires the coordination of engineering subject matter experts, field operating personnel and test technicians. Utilizing these three groups the steps involved in the construction of the Terrier Proficiency Test Battery were the following:

1. Learning the System

The engineering staff studied the available technical materials concerned with the operation of the missile and its associated test equipment and learned the circuitry and operating principles involved. In the course of this study the engineering staff developed a set of technical summary notes for Terrier. The development of such a set of notes is especially helpful for a newly developed weapon where technical materials may exist in discrete publications and require compilation and summarising. (These notes should be especially helpful for curriculum development; they are presented in Guided Missile Personnel Research: Report No. 2, Part II, A Compilation of Task Information for Terrier Missile Activities.)

2. Learning the Tasks Involved

Once the engineering staff became familiar with the equipments involved, they reviewed the specific procedures involved in testing and adjusting the missile with various test equipments and in trouble-shooting and repairing the missile and its associated test equipment. The engineering staff also studied analyses of Terrier missile tasks and maintenance data reports obtained from operating installations. (For Terrier task analyses and maintenance data reports see Guided Missile Personnel Research: Report No. 2, Part One and Part Two.)

3. Defining the Tests

On the basis of an analyses of Terrier missile tasks, the test technicians specified the kinds of tests to be developed and described the kind of test behavior to be measured by particular types of test items. The tests and the item types have been described earlier in this chapter. Each member of the engineeringg staff was provided with a handbook describing good item writing practices and listing the item types to be used for each test; in this handbook a sample itemwas included to illustrate each item type.

4. Defining Test Content

A conference was held between the engineering item writers and the test technicians to plan the content and subject matter coverage for each test. The coverage decided upon and the criteria employed are described earlier in this chapter.

Exhibit A

ITEM WRITING FORM

a.) Item Writer's Name: ____________________ b.) Test: TA TS K c.) Item Identification Number: ________

d.) Subject Matter

e.) Task or Principle Involved

f.) Item (indicate correct answer by X):

Exhibit B

ITEM CHECK LIST AND EVALUATION SHEET

Test: TA TS K
Item Number ________
Reviewer ________________

1. The correct answer is: ________________

2. Please check if statement applies. Use the back of this sheet for discussion of points checked. If you check anything in C or D, use either the back or the ITEM WRITING FORM to indicate the exact nature of criticism and recommended corrections.

   A. The Task or Principle Involved

      ( ) a. Task or Principle involved is not sufficiently important.
      ( ) b. Principle involved is important but not required for performance of job.
      ( ) c. Item does not test knowledge of stated principle or performance required by the job.
      ( ) d. Other (please specify)

   B. Level of Difficulty

      ( ) a. Item is too easy.
      ( ) b. Item is too difficult.

   C. Item Content

      ( ) a. Additional information should be supplied in stem.
      ( ) b. Problem needs clearer statement.
      ( ) c. More than one answer could be correct.
      ( ) d. Alternatives are ambiguous.
      ( ) e. One or more of the incorrect alternatives is very obviously wrong.
      ( ) f. Other (please specify).

   D. Item Structure

      ( ) a. The way the problem is stated gives a direct clue to the answer.
      ( ) b. Correct alternative or some other alternative stands out in some manner (length, wording, etc.) from the remaining answers.
      ( ) c. Other (please specify).

3. Would men just out of training school find this item easier to answer than men who have been on the job six months? Yes ______ No ______
   Why?

4. Recommendations; check one:

   ( ) a. Item is satisfactory as it now stands.
   ( ) b. Item will be satisfactory after corrections indicated have been made.
   ( ) c. Item should be discarded.

5. Writing the Item

On the basis of the foregoing preparations, the engineering staff proceeded to write test items. Particular individuals were assigned specific subject matter divisions. The first draft of an item was submitted on the Item Writing Form shown in Exhibit A. On this form the following information was placed:

a. The item writer's name.

b. The test for which the item was written. Testing and Adjustment (TA), Trouble-Shooting (TS), or Knowledge of Operation (K).

c. The item identification number. An Item was identified by a number and by the initial of the item writer. If Mr. Rohrer was writing his nineteenth item, its identification number was R-19.

d. The subject matter involved, i.e., the equipment or circuit with which the item was concerned.

e. The task or principle involved, i.e., the job procedure or the principle of operation tested by the item.

f. The item itself with the correct answer indicated.

6. First Review

The submitted item was reviewed by a member of the staff who had both engineering and test technician training. Comments were made about the technical correctness of the item and about its structure in keeping with good item writing practice.

7. Item Conference

A conference was held with the item writer to discuss and review the item. On the basis of this conference, the item was either accepted, revised, or rejected.

8. Second Engineering Review

The accepted or revised item was reviewed by an independent engineering expert. This evaluation was performed with the aid of the Item Check List and Evaluation Sheet shown in Exhibit B. This form is primarily self-explanatory. The question under 3. in this form was devised to help detect items which primarily tested school knowledge rather than job knowledge.

9. Second Conference (if necessary)

If disagreement existed between the item writer and the second reviewer on any item, a second conference was held to rework the item.

10. Item Editing

Once passed by the engineering staff, an item was edited by a test technician and prepared for inclusion in the test.

11. Drafting

The diagrams, waveforms, pictures, etc., accompanying each item were prepared by a draftsman for inclusion in the test.

12. Review by Operating Personnel

In this step of test construction, the test items were assembled into subject matter sections, e.g., items on the receiver, power supply, Flight Ready Indicator, etc., were grouped; and each section was discussed with operating personnel who were judged by their superiors to have experience with and knowledge of the particular equipment in that subject matter section. Each test item was reviewed by a group interview procedure. The item was presented to a group of individuals, and each person marked his answer; the correct answer was then given and the group members were asked to justify their answers and to explain any misunderstandings they had with the presentation of the item. From this group discussion, any necessary suggestions were obtained for revision and improvement of the item. Personnel from Guided Missile Service Unit No. 211 at the Yorktown Naval Mine Depot and U.S. Naval Guided Missile Unit No. 21 aboard the U.S.S. Mississippi cooperated in this review of test items.

The review of the test battery by operating personnel accomplished the following purposes:

a. The identification of items that were not job-oriented, e.g., items that do not reflect current job practices.

b. The identification of technically defective items and the determination of needed improvements and revisions.

c. The identification of ambiguous terms, indeterminate items, and implausible distractions (incorrect choices).

d. The identification of incorrect or defective aspects of the circuit diagrams and pictures accompanying the item.

13. Assembly into the Experimental Battery

After review by operating personnel, necessary revisions and improvements were incorporated into the test items and the items were assembled into the test booklets of the Proficiency Examination for the Terrier Missile which is presented in Appendix A. In order to keep testing sessions from being too lengthy, each of the three tests in the battery was divided into two parts, a Part A and a Part B.

The test was first administered to the graduating class of the U. S. Naval Guided Missile School in Pomona, California. The results of this administration are being analyzed and will be reported in a subsequent report.

CHAPTER II

THE TROUBLE-SHOOTING FORMBOARD

As indicated in Chapter I, trouble-shooting behavior involves the interpretation of symptoms of malfunctioning; on the basis of these symptoms, a technician isolates a trouble to a particular component of a system.[1] An important aspect of trouble-shooting behavior is that in many situations the technician observes the symptoms of malfunctioning and performs a series of checks which give him feedback information. On the basis of this information he can isolate the cause of the trouble. The test construction problem for behavior of this kind is to build a test item that supplies this feedback information. A type of item called the Tab Item has been developed to do this.[2] The trouble-shooting formboard discussed in this chapter is a modification of the Tab Item. In addition to the utility of the trouble-shooting formboard as a proficiency examination device, it can be of important use as a training aid. This is especially desirable in the present stage of the Terrier missile program where it is not feasible in many instances to obtain actual equipment for training purposes.

The trouble-shooting formboard is specifically designed to measure a technician's proficiency in trouble-shooting a complex system, in the present instance the Terrier missile system. The trouble-shooting formboard consists of several boards and cards as shown in Figures 1 and 2. These consist of:

1. A symptom card. This presents a description of a symptom of system malfunctioning; see Figure 3, and one or more of the following:

---

[1] Trouble-shooting behavior for the Terrier missile is described in Guided Missile Personnel Research: Report No. 2, Part Two: A Compilation of Task Information for Terrier Missile Activities.

[2] Glaser, R. and Damrin, D. The Tab Item: A technique for the measurement of proficiency in diagnostic problem solving tasks. A paper presented at the meetings of the American Psychological Associatio in Washington, D. C., September 1-6, 1952 (to be published).

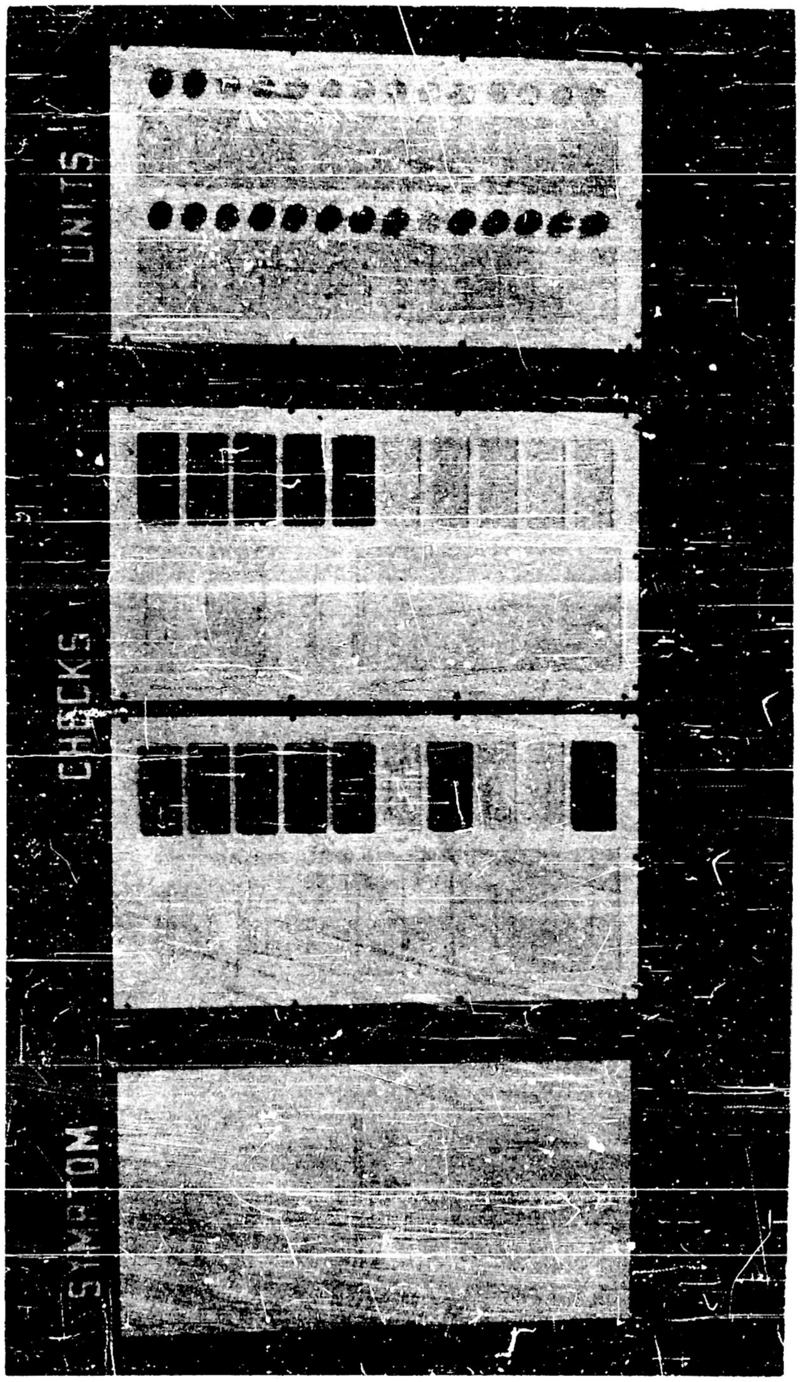

Fig. 1. A trouble-shooting formboard problem (showing a possible solution.

Fig. 2. A trainee working on a trouble-shooting formboard problem.

SYMPTOM

During a Monitoring Panel check on a Terrier Receiver, the Beam Simulator is set for 12 db error signal and -15 dbm range.

The Receiver output is measured and results obtained are as follows:

	Measured Value	Normal Value
30 cps reference voltage	0.0 V	1 to 1.4 V
30 cps error voltage	5.1 V	4.3 to 5.3 V

Fig. 3. A symptom card.

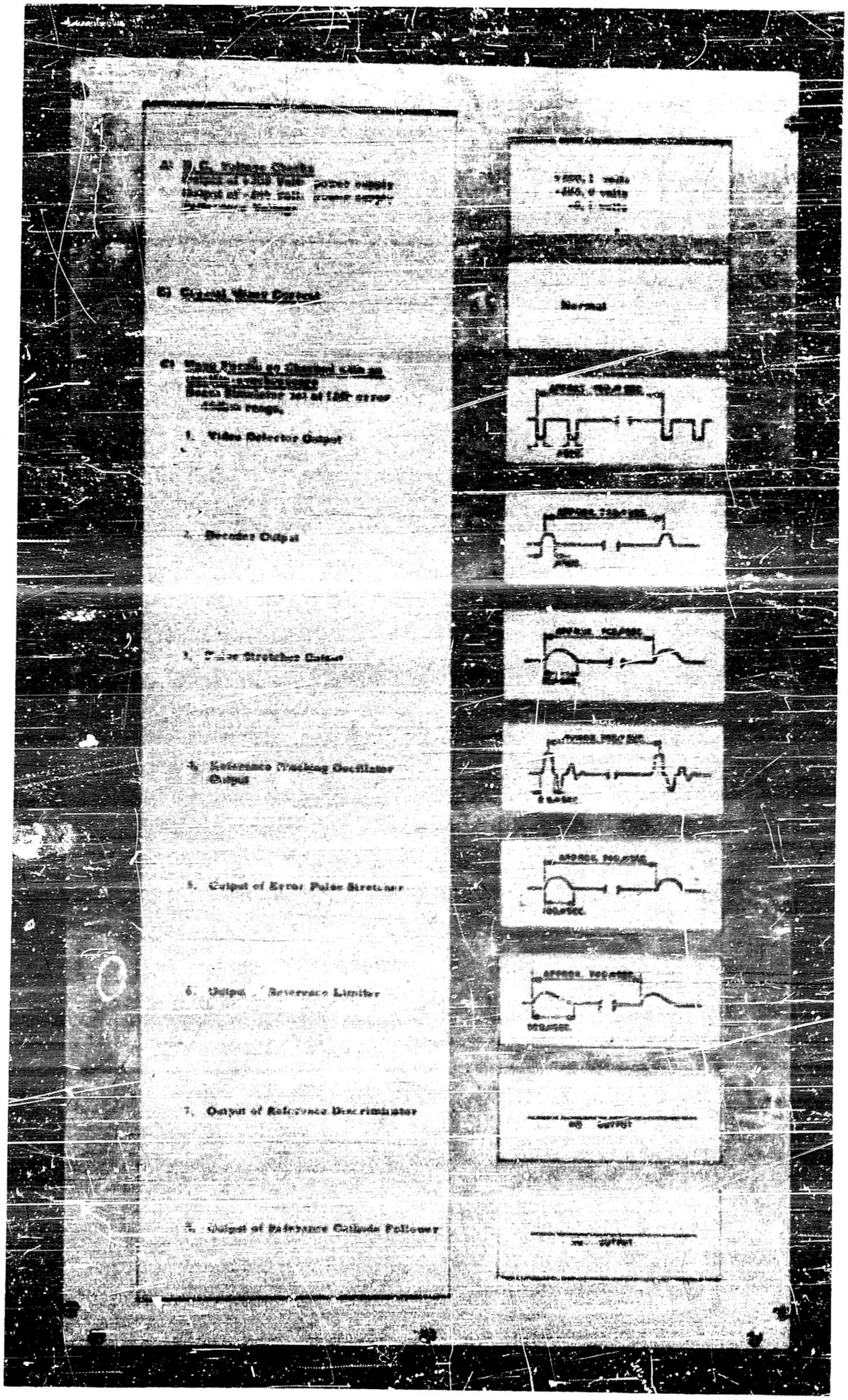

Fig. 4. A check board.

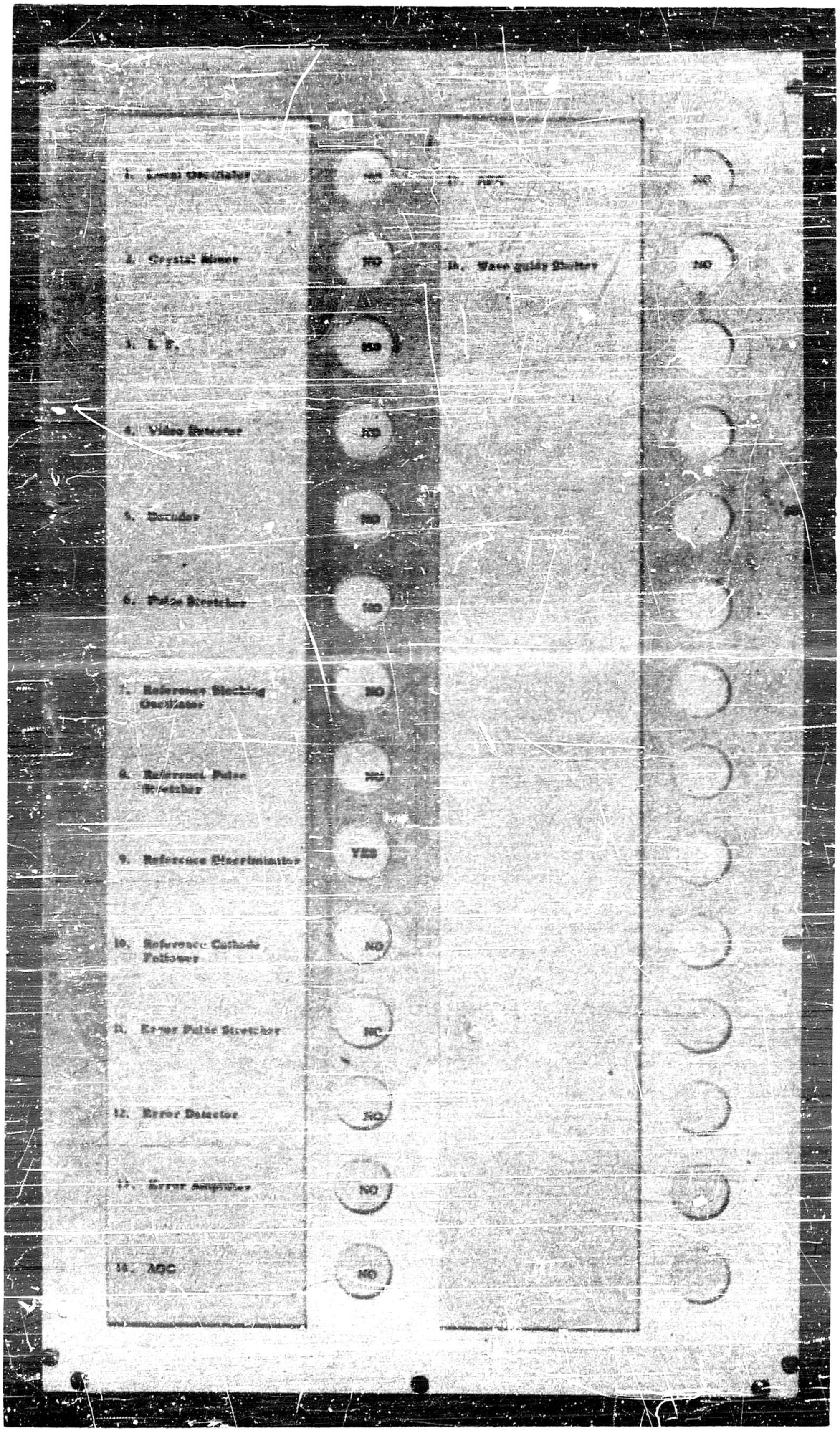

Fig. 5. A unit board.

2. A check board. This presents a series of check, testing, and alignment procedures which a technician might employ to determine the cause of malfunctioning; see Figure 4.

3. A unit board. This contains a list of components or parts in the set which might, if defective, cause the described malfunctioning; see Figure 5.

In the example given in Figure 4, it can be seen that a check board contains the following: On the left side of the board, a series of check procedures are described. On the right side opposite each of the listed check procedures are rectangles containing the results the examinee would obtain if he actually performed this check on an operating Terrier missile. For instance, in the rectangle opposite Check A in Figure 4, there are several voltage readings which he could obtain; and in the rectangle opposite Check C-1, there is a waveform he might desire to see in order to interpret the missile's performance. The information within the rectangles is not exposed to the trainee at the time he starts to work on the trouble-shooting formboard; this information is covered by a block which can be lifted off, see Figures 1 and 2.

In Figure 5, which gives an illustration of a unit board, it can be seen that the left side of the unit board contains a list of components of the system. Either the word "YES" or the word "NO" is listed in circles opposite each component. In this illustration the circle opposite unit number 9 has the word "YES" written in it; this indicates that this is the correct answer to the trouble-shooting problem, i.e., this is the component that is defective and is causing the described symptom of malfunctioning. The indications "YES" and "NO" are not exposed when a trainee starts to work on the formboard; they are covered by pegs placed in each hole. When the formboard is presented for administration, it is laid out in front of the examinee as in Figure 2, which shows an individual working on a trouble-shooting problem.

The above description should make evident that the trouble-shooting formboard attempts to reproduce a realistic trouble-shooting situation in a training situation without the use of actual equipment, which is, in many instances, difficult and expensive to obtain and expensive and time-consuming to maintain. The behavior required of an individual working on a formboard appears to approximate closely some essential aspects of the behavior required in a trouble-shooting job. In the job situation, a technician generally receives a report of malfunctioning through a written or verbal report, or by indications on test or alignment equipment with which he is working. He then proceeds to check through the system in an attempt to discover and isolate the cause of the trouble. In the trouble-shooting formboard, the technician

is presented with a description of malfunctioning; and then, rather than actually performing various check procedures, he lifts off the blocks of those checks he would make if he were trouble-shooting a real system. Whenever he lifts a block, i.e., makes a check, he receives the information he would obtain if he actually performed that check on a functioning system. When the trainee pulls a peg on the unit board, he is informed whether or not a particular component is defective. The word "YES" informs him that the component is defective and that he has solved the problem by locating the defective component. The word "NO" indicates that the particular component examined is not defective and trouble-shooting must continue. The words "YES" and "NO" duplicate the on-the-job procedure of checking a component which the technician has reason to believe might be faulty. For example, a tube might be tested and found to be short-circuited thus indicating "YES, this is the cause of the trouble." On the other hand, the tube might test out normally, thus indicating that "NO, this is not the cause of the trouble."

In working on the trouble-shooting formboard, the trainee is instructed to locate the defective unit by making as few checks as possible. He is free to select any single check, or combination of checks, he thinks necessary to obtain the information which he needs to isolate the trouble to a specific unit. When he reaches this point, he pulls the peg beside the selected unit and is informed as to the correctness of his diagnosis. If he finds a "YES", he has located the trouble and has solved that particular problem. If he finds a "NO", he is free to go back and obtain additional information by performing additional check procedures before making another diagnosis. The trainee is specifically instructed that he will be penalized for making erroneous diagnoses, i.e., pulling "NO" unit pegs; this is done to minimize the location of the "YES" unit by guessing. Detailed instructions for administering the trouble-shooting formboard are presented in Appendix C.

Construction of the Trouble-Shooting Formboard

As indicated, the material presented in a trouble-shooting formboard consists of the following:

A. The symptom of malfunctioning

B. The check procedures

C. The results of the check procedures (under blocks)

D. The possibly defective components

Specific considerations concerning the construction of each of these will now be discussed.

A. The symptom of malfunctioning. The description of the symptom must be clearly and carefully presented. Ambiguity in the description can force the trainee to perform unrealistic checks for the purpose of clarifying the exact nature of the malfunctioning rather than for the purpose of isolating the defect. If this occurs, a measure of the trainee's ability to understand what the constructor of the formboard problem meant is obtained in addition to his ability to trouble-shoot. A symptom is best presented in terms of the specific test equipment and operating indications that are part of the job. Wherever applicable, a diagram, picture, or check sheet should be used to present the symptom.

B. The check procedures. The checks included in each formboard item must present a wide variety of trouble-shooting procedures--from those which are very relevant to the detection of the cause of the trouble involved, to those which are quite irrelevant. This serves the double purpose of (1) presenting the trainee with a situation that retains some of the unstructured aspects of the actual job situation, and (2) permitting the wide range of scores necessary for discriminating among several levels of proficiency. These considerations have led to the inclusion of checks of the following types, classified according to the information which they provide:

1. Relevant. Information that is pertinent or essential to the detection of the faulty component. (A very proficient mechanic would utilize these procedures.)
2. Additional. Extra information that a less proficient mechanic might need for solution of the problem, but that a highly proficient one could infer from either the description of malfunctioning or the relevant checks.
3. Redundant. Information which duplicates the information given by a previously performed check.
4. Inadequate. Information which is contained as part of the information given by other more comprehensive checks of the relevant type.
5. Irrelevant. Information which is completely unrelated to the solution of the problem. (Only mechanics with a very low degree of proficiency would utilize these procedures.)

C. The results of the check procedures. As in the description of malfunctioning, the results given under the block for each

check in the item must be unambiguous and technically accurate. To help insure freedom from ambiguity, a picture or diagram is given wherever possible. The use of a picture or a diagram also serves to lessen the importance of the trainee's ability to visualize verbally-presented material. An obtained result may be shown in comparison with the normal result or it may be stated that the obtained result is in or out of tolerance. This is desirable for results which a trainee would not be expected to interpret offhand on the job and would require that he refer to a manual or check-list.

D. The possibly defective components. Considerations similar to those mentioned for the construction of the check procedures are necessary in selecting the units to be included. The units from which the trainee is to select in making his diagnosis are of the following kinds:

1. Correct. The component that is causing the described trouble.

2. Plausible. Components which could cause the described trouble, but which can be eliminated by performing certain combinations of checks given in the item. For each plausible unit there exist one or more check procedures which, if performed and if properly interpreted, will permit the trainee to eliminate that component from consideration.

3. Irrelevant. Components which could not possibly cause the described trouble.

In actual physical construction, the trouble-shooting formboard can consist of a hardboard or sheet-metal frame. The frame consists of a front panel with rectangles (or holes) cut out as shown in Figure 6 and 7; the back panel is a solid panel with no cut-out apertures. The front and back panels are riveted together with enough space between the two to slide a card made of stiff cardboard. Figure 6 shows an item card being inserted into a check board. The blocks for check boards are made of wood and the pegs for unit boards can be cut from wood dowels. The blocks and pegs should be painted a dark color so that markings and fingerprints will not distinguish the most popularly used checks and units. Detailed specifications for the construction of check and unit formboards are given in Figure 7.

A single trouble-shooting formboard item consists of a symptom card, one or more check boards, and one or more unit boards depending upon the number of check procedures and units involved in a particular problem. Each problem is set up on cards, a symptom card and check and unit cards; the check and unit cards are inserted into check and unit boards. For every new problem or form-

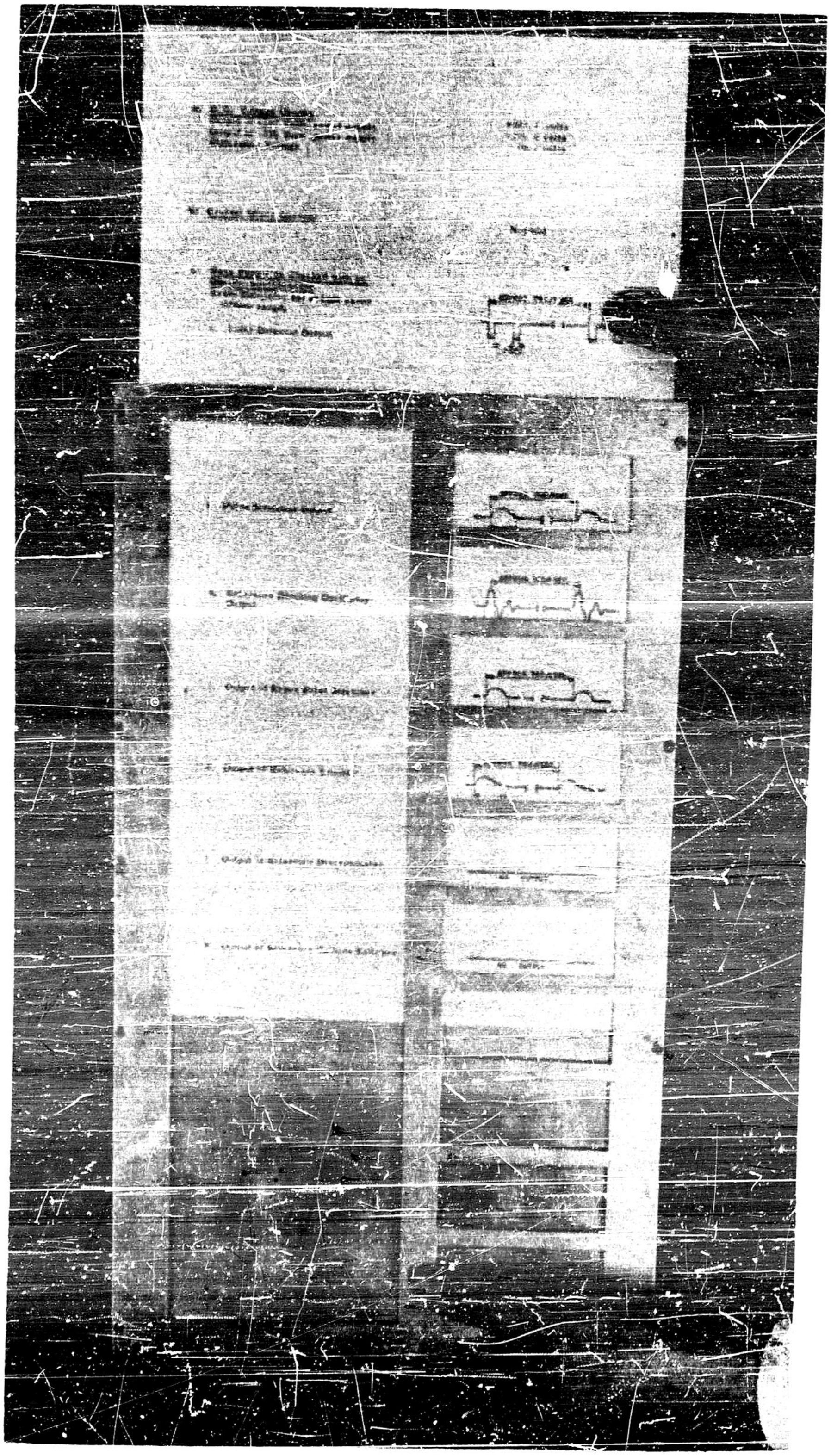

Fig. 6. Inserting an item card in a formboard frame.

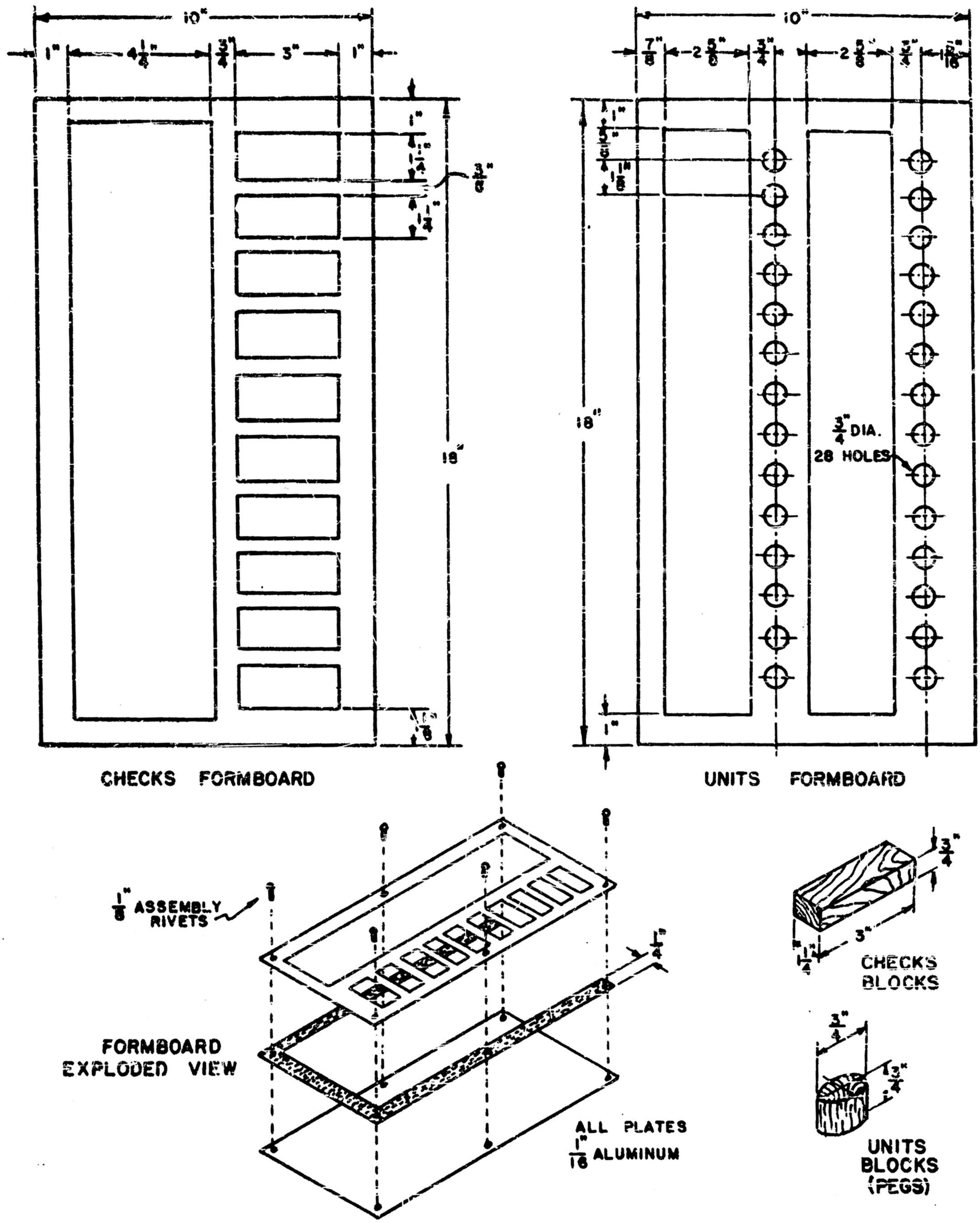

FIG. 7

TROUBLESHOOTING FORMBOARD SPECIFICATIONS

board item presented to a trainee, new cards are used and the necessary number of boards are employed. It is advisable to keep the number of check boards to about four or five or less and the number of unit boards to one or two or else the situation becomes unwieldy and too much material is presented to a trainee at one time.

Each set of cards that make up one trouble-shooting problem can be considered as one test item and the thirteen steps described in Chapter 1 for the development of Terrier multiple-choice items were employed for the development of the formboard items. Experimental trouble-shooting formboard items developed for the Terrier missile are presented in Appendix B.

With respect to the content coverage of these items, most of the formboard items involve more than one of the sub-systems of the missile or associated test equipment. The specific malfunctioning equipment and defective unit with which each item is concerned is listed below:

Item No.	Malfunctioning Equipment and the Defective Unit
1	receiver package, reference discriminator
2	receiver package, automatic gain control
3	receiver package, crystal mixer
4	guidance package
5	guidance package, "B" channel reference driver
6	guidance package, first limiter
7	power supply package
8	power supply package, choke
9	electrical system, power change-over relay
10	hydraulic system, autopak
11	hydraulic system, alternator-hydraulic motor
12	hydraulic system, hydraulic valve-rolleron actuator
13	hydraulic system, "A" channel hydraulic valve
14	monitoring panel, resistor in dc amplifier
15	monitoring panel, transformer in electronic chassis

Scoring the Trouble-Shooting Formboard Items

Several methods for scoring performance on a trouble-shooting formboard problem are under consideration. The empirical data obtained from the application of the various scoring procedures must be compared and evaluated.

A proficient trouble-shooter may be assumed to be one who will detect a source of malfunctioning most efficiently, with a minimum of activity. On this assumption, when working on the trouble-shooting formboard, he will select a minimum number of relevant check procedures and proceed to identify the defective component with a minimum number of pulled pegs. A poor trouble-shooter, on the other hand, may be considered as one who will need more information, will perform non-essential procedures, and will make more erroneous diagnoses. Accordingly, the simplest method of scoring a formboard trouble-shooting problem is a straight frequency count of the combined number of the blocks and pegs pulled. In this method, the greater the score the poorer the performance of the trainee.

A more complex method involves a weighted error count wherein the procedures and units which can be selected are weighted in inverse relation to their relevance in isolating the defective unit. The weights are based upon the kinds of checks and components which the examinee selects. (See B and D under Construction of the Trouble-Shooting Formboard.) With respect to the check procedures, relevant checks are weighted minimally and irrelevant ones maximally. Additional checks receive a weighting intermediate between these two. Redundant and inadequate checks by definition are meaningful only in terms of related procedures and thus are weighted only as they appear in pre-determined combinations. For example, if a check has been performed which gives certain information and then a subsequent check is performed which gives identical information, the latter check is redundant and receives extra weight. With respect to the units, the relevant unit receives a zero weighting and irrelevant units receive maximum weighting. Plausible units are weighted so as to penalize guessing; if a "NO" unit peg is pulled and the check procedures which relate to it have not been pulled, the unit is weighted maximally on the assumption that the trainee is guessing.

A somewhat different scoring technique is based upon the fact that a very proficient trouble-shooter will isolate a defect in the shortest possible time. Weighting of checks and units can be based on the time required to perform check procedures and to get at and examine possible defective units. With this scoring method, the trainee is instructed that his performance on the trouble-shooting formboard will be scored on the basis of the time required to perform the identical operations with the actual equipment. He receives least weight (less time penalty) for those checks and units he selects which require the least amount of time to perform on the job. A man who performs a trouble-shooting job more efficiently in terms of the shortest amount of time receives a low time score. This scoring procedure introduces a desirable realistic bias. On the job a technician will often perform quick and simple checks before undertaking an involved and complex procedure, and he may

also investigate easily accessible units first before investigating units which are more difficult to get at. If these checks give the technician the information he needs, he may save the time required to perform the more lengthy checks. If the quick and simple checks do not provide him with the necessary information, he has lost only a short amount of time and can procede with the more time-consuming checks. This scoring method takes into account a man's ability to consider the "time efficiency" in his trouble-shooting behavior. The feasibility of the procedure is being studied.

Trouble-shooting and the trouble-shooting formboard involve the presentation of an information series; and the possibility of the application of the concepts of a recently developed mathematical theory of information has been studied (Shannon, C. E. and Weaver W. The mathematical theory of communication. The University of Illinois Press: Urbana, Illinois, 1949). A procedure has been developed for scoring a trouble-shooting problem based on this theory. Discussion of this is presented as a seperate technical note in Appendix D.

General Comments

An important limitation of the trouble-shooting formboard is that it does not measure the manipulative skills involved in the performance of a check procedure. In addition, it makes demands upon the trainee's verbal ability and upon his ability to visualize the functioning of a piece of complex equipment when it is not actually before him. A particular set of behaviors is required for a mechanic to actually perform a series of control settings and then measure a specific voltage output, while a somewhat different, but related, set of behaviors is necessary for him to read that certain control settings have been made and then select a particular procedure. This discrepancy between test behavior and job behavior is not unique to formboard items, and validation data usually inform us of the seriousness of this discrepancy.

Since a single formboard item yields a range of scores rather than the usual pass-fail indication for a test item, some problems arise concerning the application of conventional item statistics. It is possible to employ the techniques based on dichotomous responses by establishing an arbitrary pass-fail cutting point in the range of item scores, but such dichotomizing of data may sacrifice useful information. An alternative procedure for computing an index of item difficulty is to use the average number of pulls required by a group of trainees for each item. Subtracting this average score from the minimum number of pulls necessary to solve an item yields the average amount of the deviation from a perfect score. This or some function of it can be taken as an index of

item difficulty. The minimum number of pulls is determined on the basis of expert opinion and analysis of item responses. For the computation of item validity, there appear to be no special problems. The entire range of item scores may be used in correlations with criterion scores if desired.

In conclusion, it should be emphasized that the trouble-shooting formboard can be utilized both as proficiency measurement procedure and as a training aid. During periods when equipment is scarce for training purposes, the use of the formboard may offer an inexpensive and practical procedure for training in trouble-shooting techniques.